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1976 ANNUAL REPORT

FOR

RBOSP REVEGETATION PROGRAM
'76 Annual Report

SUBMITTED TO

RIO BLANCO OIL SHALE PROJECT
DENVER, COLORADO

SUBMITTED BY

NUS CORPORATION
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THE 1976 ANNUAL REPORT FOR THE RBOSP REVEGETATION PROGRAM

The revegetation program for Tract C-a is designed to investigate current revegetation technology and to develop a plan to successfully reestablish a plant community on the processed shale disposal pile in accordance with the environmental stipulations in the oil shale lease. This revegetation plan will be developed as a result of extensive field experiments and laboratory studies designed to provide data pertinent to Tract C-a.

Revegetation experiments were initiated in 1975 and 1976. The results of these studies will be discussed in separate sections of this report. Section 1 will discuss data collected during the first growing season of the experiments initiated in the fall of 1975. Section 2 will outline the objectives, methods and preliminary results of the experiments initiated in the fall of 1976.

1.0 - REVEGETATION EXPERIMENTS INITIATED IN 1975

1.1 Objectives

The 1975 revegetation experiments are designed for the following:

- to determine which species when sown in a composite species mixture are most adapted to the physical and environmental conditions existing on Tract C-a
- to determine the effectiveness of several mulches in aiding establishment of the sown plant species
- to determine the effects of fertilizer applied at different time periods on the sown plant species
- to determine the effects of aspect on the establishment of the sown species.

1.2 Methods

The revegetation experiments initiated in 1975 utilize two locations, R_1 located on a northwest exposure and R_2 located on a southeast exposure. A total of 16 treatments, with 3 replicates of each treatment, were applied at each site in a randomized block design. A detailed description of the methods utilized in the 1975 revegetation experiments is presented in Section 2.5. 3.2 of Progress Report 4 (October 1975). The statistical analyses for the 1975 revegetation experiments are presented in Section 2.5.3.2 of Progress Report 5 (January, 1976).

1.3 Results and Discussion

1.3.1 Emergence Density Data

Measurements of emergence density (individuals/ha) at R_1 and R_2 were conducted during June, 1976. The emergence density data for each of the four permanent subplots within a treatment plot at each location are presented in Appendix

1-1. A summary of the emergence density data for the three replicates (blocks) of each treatment at each location is presented in Appendix 1-2.

The planted grasses with the greatest number of emerged seedlings (Appendix 1-2) were wheatgrass species (Agropyron spp. is A. smithii and A. riparium) and Luna pubescent wheatgrass (Agropyron trichophorum). Indian ricegrass (Oryzopsis hymenoides) was more common on R_1 than R_2 and was equal in number to Luna pubescent wheatgrass. Green needlegrass (Stipa viridula) was co-dominant with Luna pubescent wheatgrass on R_1. Basin wildrye was more common on R_2 than R_1 but this species had the lowest density of the six grasses planted.

Yellow sweet clover (Melilotus officinalis) was the dominant forb present on the revegetation plots (Appendix 1-2). Rocky mountain penstemon (Penstemon strictus), cicer milkvetch (Astragalus cicer), and blue flax (Linum lewisii) were common subdominants. No scarlet globemallow was encountered during June of 1976, but several individuals, possibly invaders, appeared in the fall of 1976. The lack of scarlet globemallow germination is probably attributable to poor seed quality since the species' presence on tract indicates its adaptability to the local environment.

Rabbitbrush species (Chrysothamnus spp. is C. viscidiflorus and C. nauseosus) were the most abundant shrubs on R_1 (Appendix 1-2). Other common shrubs include winterfat (Eurotia lanata) and four=wing saltbush (Atriplex canescens). On R_2, the rabbitbrush species and bitterbrush (Purshia tridentata) were co-dominants while winterfat and four-wing saltbush were less abundant. All the planted woody species germinated with the exception of Utah juniper (Juniperus osteosperma). It was expected that Utah juniper would not germinate in 1976 since it needs a warm-cold stratification sequence to break dormancy (U.S.D.A. Forest Service, 1974). Since planting occurred in the fall of 1975, the warm-cold stratification periods will not be complete until spring of 1977.

Plant species at R_1 with the highest percent emergence (Table 1-1) were generally those species which had the highest emergence density. The wheatgrass species Luna pubescent wheatgrass, cicer milkvetch, bitterbrush, winterfat, and pinyon pine had the highest percent emergence among the planted species. Pinyon pine had an exceptionally high percent emergence of 53%. The pinyon pine seed used for the 1975 experiments was collected in fall of 1975 from the pinyon-juniper habitat surrounding the revegetation plots. Percent emergence was not calculated for plant species at R_2 since a snowfall which occurred on June 14, 1976, following completion of the emergence density measurements, caused additional germination. Therefore, percent emergence estimates for R_2 do not reflect the true percent emergence.

Barley (Hordeum vulgare) and Russian thistle (Salsola kali) were common invaders carried onto the treatment plots at both R_1 and R_2 with the straw mulch. The most common invaders from the surrounding area were the forbs twinpod (Physaria floribunda), skyrocket gilia (Ipomopsis aggregata), and lobeleaf groundsel (Senecio multilobatus). Lupine (Lupinus sp.) was common on R_1.

An Analysis of Variance (ANOVA) was performed to test the following hyptheses for each of the dependent variables (number of emerged seedlings, number of surviving seedlings, and percent cover):

H_{01}: All sixteen (16) treatment means are equal.
H_{11}: At least one of the 16 treatment means is different.

H_{02}: All four (4) mulch treatment means are equal.
H_{12}: At least one of the mulch treatment means is different.

H_{03}: All four (4) fertilizer treatment means are equal.
H_{13}: At least one of the fertilizer treatments is different.

H_{04}: The differences among the mulch means are equal across fertilizers.
H_{14}: At least one of the differences among the mulch means is different across fertilizers.

H_{05}: All twenty-one (21) planted species means are equal.
H_{15}: At least one of the planted species means is different.

TABLE 1-1

PERCENT EMERGENCE OF SPECIES PLANTED ON THE RBOSP REVEGETATION PLOT R_1

	% Emergence
Grasses	
Agropyron trichophorum	32
Agropyron spp.	31
Elymus cinereus	2
Oryzopsis hymenoides	3
Stipa viridula	3
Forbs	
Astragalus cicer	10
Hedysarum utahensis[1]	--
Linum lewisii	4
Melilotus officinalis[1]	--
Penstemon strictus[1]	--
Sphaeralcea coccinea	0
Shrubs	
Artemisia tridentata	< 1
Atriplex canescens	4
Cercocarpus montanus	4
Chrysothamnus spp.	1
Eurotia lanata	8
Juniperus osteosperma	0
Pinus edulis	53
Purshia tridentata	18
Rhus trilobata	< 1

[1]Percent emergence not calculated since number of seeds/lb not available.

H_{06}: The differences among the species means are equal across treatments.
H_{16}: At least one of the differences among the species means is different across treatments.

H_{07}: The differences among the species means are equal across mulches.
H_{17}: At least one of the differences among the species means is different across mulches.

H_{08}: The differences among the species means are equal across fertilizers.
H_{18}: At least one of the differences among the species means is different across fertilizers.

H_{09}: The differences among the species means are equal across fertilizers and mulches.
H_{19}: At least one of the differences among the species means is different across fertilizers and mulches.

The results of the ANOVA are listed in Table 1-2 for location R_1 and Table 1-3 for location R_2.

The F-ratio is calculated by dividing the mean square listed in the numerator by the mean square listed in the denominator for the terms listed under the sources of variation. This calculated result is then compared to the appropriate F-value in a standard table (A-Table 5) (Pearson and Hartley, 1972) for a given pair of degrees of freedom. Those results that are statistically significant at the 0.05 and 0.01 level are identified by asterisk(s). For purposes of this report the discussion will be limited to the significant main treatment effects of mulch and fertilizer.

For R_1 the AVOVA table (Table 1-2) for emergence density indicates that the statistical hypotheses H_{02}, H_{05}, H_{07}, and H_{08} are rejected at the stated levels of significance. The rejection of H_{02} indicates that at least one of the mulch treatment means is different.

Duncan's multiple range test (Duncan, 1955) was used to compare the mulch treatment means to determine which means are different and which means are equivalent. The results of applying Duncan's multiple range test to the mulch treatment means for emergence density at location R_1 suggests that

TABLE 1-2

ANALYSIS OF VARIANCE TABLE FOR LOCATION R_1

	Source of Variation	Degrees of Freedom		Mean Square for Emergence (Individuals/ha)	Mean Square for Survival (Individuals/ha)	Mean Square for Percent Cover	F-Ratio
1.	Block	2		21,415,402,000	11,672,395,833	2.4556052	
2.	Treatment	15		61,060,608,000	38,237,460,317	13.7326554**	(2/6) H_{01}
3.	Mulch		3	55,408,399,000**	12,940,145,503*	24.5200893**	(3/7) H_{02}
4.	Fertilizer		3	143,914,750,000	93,343,055,556	19.9909888*	(4/8) H_{03}
5.	Mulch * Fertilizer		9	35,326,631,000	28,301,366,843	8.0507330	(5/9) H_{04}
6.	Block * Treatment	30		48,339,899,000	22,491,999,008	3.0606316	
7.	Block * Mulch		6	4,399,495,700	2,257,977,844	1.2869544	
8.	Block * Fertilizer		6	89,540,369,000	37,764,756,944	2.2975364	
9.	Block * Mulch * Fertilizer		18	49,253,210,000	24,145,753,417	8.0507330	
10.	Species	20		1,123,431,900,000**	431,856,733,631**	72.2296379**	(10/15) H_{05}
11.	Treatment * Species	300		18,449,845,000	8,157,797,123**	1.8299818**	(11/16) H_{06}
12.	Mulch * Species		60	10,566,802,000**	3,351,760,086**	4.2525546**	(12/17) H_{07}
13.	Fertilizer * Species		60	41,748,707,000*	18,710,364,583**	1.7769263**	(13/18) H_{08}
14.	Mulch * Fertilizer * Species		180	13,311,238,000	6,242,286,982	1.0401427**	(14/19) H_{09}
15.	Block * Species	40		4,061,990,300	1,966,640,625	1.4946677	
16.	Block * Species * Treatment	600		16,400,765,000	5,421,049,355	0.6535830	
17.	Block * Species * Mulch		120	4,516,882,900	1,201,493,469	0.5329613	
18.	Block * Species * Fertilizer		120	25,866,957,000	7,627,821,181	0.6959739	
19.	Block * Species * Mulch * Fertilizer		360	17,206,662,000	6,091,977,375	0.6796599	
	Remainder	3024		10,840,443,000	4,565,294,312	0.7429729	
	Total	4031		18,158,513,000	7,316,518,411	1.2391451	

*Significant at the 0.05 level
**Significant at the 0.01 level

TABLE 1-3

ANALYSIS OF VARIANCE TABLE FOR LOCATION R_2

	Source of Variation	Degrees of Freedom	Mean Square for Emergence (Individuals/ha)	Mean Square for Survival (Individuals/ha)	Mean Square for Percent Cover	F-Ratio
1.	Block	2	2,100,892,857	1,083,358,135	1.0672123	
2.	Treatment	15	9,864,861,111**	6,198,490,410**	2.5809524	(2/6)H_{01}
3.	Mulch	3	23,916,699,735*	15,631,638,558*	5.5443122*	(3/7)H_{02}
4.	Fertilizer	3	6,555,712,963	3,147,974,537	1.8313492	(4/8)H_{03}
5.	Mulch * Fertilizer	9	6,283,630,952	4,070,946,318	1.8430335	(5/9)H_{04}
6.	Block * Treatment	30	2,863,670,635	2,140,395,172	1.3672123	
7.	Block * Mulch	6	3,105,787,037	2,565,467,923	1.1323578	
8.	Block * Fertilizer	6	1,459,292,328	1,454,125,331	1.2031250	
9.	Block * Mulch * Fertilizer	18	3,251,091,270	2,227,460,869	1.5001929	
10.	Species	20	128,382,008,929**	120,388,536,706**	42.3525546**	(10/15)H_{05}
11.	Treatment * Species	300	2,721,715,278**	1,230,295,966**	0.6939038**	(11/16)H_{06}
12.	Mulch * Species	60	5,219,859,458**	2,881,360,780**	1.9465691**	(12/17)H_{07}
13.	Fertilizer * Species	60	1,965,497,685**	568,391,204	0.4676339	(13/18)H_{08}
14.	Mulch * Fertilizer * Species	180	2,141,073,082**	900,575,948**	0.3517719	(14/19)H_{09}
15.	Block * Species	40	1,606,752,232	317,941,468	0.2674727	
16.	Block * Species * Treatment	600	971,863,343	576,950,728	0.3880283	
17.	Block * Species * Mulch	120	1,045,951,968	436,960,979	0.4395627	
18.	Block * Species * Fertilizer	120	538,415,592	435,166,997	0.3558160	
19.	Block * Species * Mulch * Fertilizer	360	1,091,649,719	670,875,220	0.3815876	
	Remainder	3024	2,134,143,519	1,201,033,399	0.4431217	
	Total	4031	2,660,202,848	1,718,439,233	0.6749202	

*Significant at the 0.05 level
**Significant at the 0.01 level

significant differences exist among each of the four means. The multiple comparison of average emergence density of mulch treatments (Table 1-4) indicates that plantings with straw results in greater emergence than each of the other three mulch treatments.

For R_2 the ANOVA table (Table 1-3) for emergence indicates that the statistical hypotheses H_{01}, H_{02}, H_{05}, H_{06}, H_{07}, H_{08}, and H_{09} are rejected. The rejection of H_{02} indicates that at least one of the mulch treatment means is different. The multiple range test (Duncan's) of the mulch treatment means at R_2 suggests that each of the means is significantly different. Comparison of the average emergence density of mulch treatments (Table 1-5) indicates that plantings with straw result in higher emergence density than do the other three mulch treatments.

An ANOVA was performed to test each plant species and group of plant species at R_1 and R_2 with respect to the number of emerged seedlings. The results of these ANOVA are listed in Appendix 1-3.

1.3.2 Survival Density Data

Measurements of survival density (individuals/ha) at R_1 and R_2 were performed during August and September 1976. The survival density data for each of the four permanent subplots within a treatment plot at each location are presented in Appendix 1-4. A summary of the survival density data for the three replicates (blocks) of each treatment at each location is presented in Appendix 1-5.

Species with the greatest number of seedlings surviving the first growing season at R_1 and R_2 are similar to those with the greatest number of emerged seedlings (Appendix 1-5). Only one species, basin wildrye, did not survive the first growing season at either R_1 or R_2. The relative abundance of surviving invader species is also similar to that of emerged seedlings except that the abundance of lupine was reduced at R_1.

TABLE 1-4

SUMMARY OF AVERAGE EMERGENCE DENSITY (INDIVIDUALS/HA) OF PLANTED SPECIES IN EACH OF SIXTEEN TREATMENTS AT THE RBOSP REVEGETATION SITE R_1 DURING JUNE, 1976

Mulch	Fertilizer Application	Planted
None	None	767,500
None	Fall	107,500
None	Spring	548,333
None	Fall-Spring	670,000
Hydromulch	None	885,833
Hydromulch	Fall	439,167
Hydromulch	Spring	410,000
Hydromulch	Fall-Spring	135,000
Straw	None	808,333
Straw	Fall	760,833
Straw	Spring	1,015,000
Straw	Fall-Spring	535,000
Netting & Straw	None	1,229,166
Netting & Straw	Fall	179,167
Netting & Straw	Spring	996,667
Netting & Straw	Fall-Spring	562,500

Average Density of Mulch Treatments	
None	523,333
Hydromulch	467,500
Straw	779,792
Netting & Straw	741,875

Average Density of Fertilizer Treatments	
None	922,708
Fall	371,667
Spring	742,500
Fall-Spring	475,625

TABLE 1-5

SUMMARY OF AVERAGE EMERGENCE DENSITY (INDIVIDUALS/HA) OF PLANTED SPECIES IN EACH OF SIXTEEN TREATMENTS AT THE RBOSP REVEGETATION SITE R_2 DURING JUNE, 1976

Mulch	Fertilizer Application	Planted
None	None	271,667
None	Fall	169,167
None	Spring	136,667
None	Fall-Spring	85,833
Hydromulch	None	180,000
Hydromulch	Fall	194,167
Hydromulch	Spring	378,333
Hydromulch	Fall-Spring	294,167
Straw	None	439,167
Straw	Fall	204,167
Straw	Spring	396,667
Straw	Fall-Spring	570,833
Netting & Straw	None	106,667
Netting & Straw	Fall	193,333
Netting & Straw	Spring	270,833
Netting & Straw	Fall-Spring	283,333

Average Density of Mulch Treatments	
None	165,833
Hydromulch	261,667
Straw	402,709
Netting & Straw	213,542

Average Density of Fertilizer Treatments	
None	249,375
Fall	190,208
Spring	295,625
Fall-Spring	308,542

Percent survival for planted and invader species at R_1 (Table 1-6) was higher for the hydromulch and no mulch treatments than it was for the straw mulches. Since mulch is expected to effect survival rates directly it might be concluded that straw mulch is less effective than hydromulch in increasing survival. Plant densities must also be considered before reaching conclusions regarding the effectiveness of various mulches in improving plant establishment. Percent survival was not calculated for R_2, as discussed in Section 1.3.1.

For R_1 the ANOVA table (Table 1-2) for survival density indicates that the statistical hypotheses H_{02}, H_{05}, H_{06}, H_{07}, and H_{08} are rejected. The rejection of H_{02} indicates that at least one of the mulch treatment means is different The results of the multiple range test indicate that plantings with hydromulch and the plantings with no mulch are equivalent and that each of the other two mulch treatments are different. Comparison of the average density of mulch treatments (Table 1-7) indicate that plantings with straw plus netting resulted in the highest survival densities at R_1.

For R_2 the ANOVA table (Table 1-3) for survival indicates that the following statistical hypotheses should be rejected: H_{01}, H_{02}, H_{05}, H_{06}, H_{07}, and H_{09}. As with R_1, the rejection of H_{02} indicates that at least one of the mulch treatment means is different. However, the multiple range test of survival treatment means at R_2 suggests that the four treatment means are different. The average survival density of mulch treatments (Table 1-8) indicates that plantings with straw mulch resulted in the highest survival densities at R_2.

An ANOVA was prepared to test each plant species and group of plant species at R_1 and R_2 with respect to the number of surviving seedlings. The results of these ANOVA are listed in Appendix 1-6.

TABLE 1-6

PERCENT SURVIVAL OF PLANTED SPECIES FOR EACH TREATMENT APPLIED TO THE RBOSP REVEGETATION PLOT R_1

Mulch	Fertilizer	Planted
None	None	78
None	Fall	95
None	Spring	72
None	Fall-Spring	88
Hydromulch	None	85
Hydromulch	Fall	99
Hydromulch	Spring	83
Hydromulch	Fall-Spring	95
Straw	None	68
Straw	Fall	65
Straw	Spring	68
Straw	Fall-Spring	66
Netting & Straw	None	89
Netting & Straw	Fall	67
Netting & Straw	Spring	64
Netting & Straw	Fall-Spring	70

Average Percent Cover for Mulch Treatments	
None	83
Hydromulch	91
Straw	67
Netting & Straw	73

Average Percent Cover for Fertilizer Treatments	
None	80
Fall	82
Spring	72
Fall-Spring	80

TABLE 1-7

SUMMARY OF AVERAGE SURVIVAL DENSITY (INDIVIDUALS/HA) OF PLANTED SPECIES IN EACH OF SIXTEEN TREATMENTS AT THE RBOSP REVEGETATION SITE R_1 DURING AUGUST-SEPTEMBER 1976

Mulch	Fertilizer Application	Planted
None	None	595,000
None	Fall	102,500
None	Spring	393,333
None	Fall-Spring	586,667
Hydromulch	None	750,833
Hydromulch	Fall	436,667
Hydromulch	Spring	338,333
Hydromulch	Fall-Spring	128,333
Straw	None	549,167
Straw	Fall	498,333
Straw	Spring	693,333
Straw	Fall-Spring	352,500
Netting & Straw	None	1,097,500
Netting & Straw	Fall	120,833
Netting & Straw	Spring	640,833
Netting & Straw	Fall-Spring	395,833

Average Density of Mulch Treatments

None	419,375
Hydromulch	413,542
Straw	523,333
Netting & Straw	563,750

Average Density of Fertilizer Treatments

None	748,125
Fall	289,583
Spring	516,458
Fall-Spring	365,833

TABLE 1-8

SUMMARY OF SURVIVAL DENSITY (INDIVIDUALS/HA)
OF PLANTED SPECIES IN EACH OF SIXTEEN TREATMENTS AT THE
RBOSP REVEGETATION SITE R_2 DURING AUGUST-SEPTEMBER
1976

Mulch	Fertilizer Application	Planted
None	None	230,000
None	Fall	193,333
None	Spring	137,500
None	Fall-Spring	125,833
Hydromulch	None	217,500
Hydromulch	Fall	220,000
Hydromulch	Spring	395,833
Hydromulch	Fall-Spring	250,833
Straw	None	367,500
Straw	Fall	250,000
Straw	Spring	344,167
Straw	Fall-Spring	483,333
Netting & Straw	None	115,833
Netting & Straw	Fall	194,167
Netting & Straw	Spring	255,833
Netting & Straw	Fall-Spring	316,667
Average Density of Mulch Treatments		
None		171,667
Hydromulch		271,042
Straw		361,250
Netting & Straw		220,625
Average Density of Fertilizer Treatments		
None		232,708
Fall		214,375
Spring		283,333
Fall-Spring		294,167

1.3.3 Percent Cover Data

Measurements of percent cover at R_1 and R_2 were conducted during August and September 1976. The percent cover data for each of the four permanent subplots within a treatment plot at each location are presented in Appendix 1-7. A summary of the percent cover data for the three replicates (blocks) of each treatment at each location is presented in Appendix 1-8.

The percent cover at R_1 (25%) (Table 1-9) was approximately 30% higher than at R_2 (17%) (Table 1-10). The plant species which contributed the greatest portion of total cover were the wheatgrass species, Luna pubescent wheatgrass, yellow sweet clover, barley, and Russian thistle (Appendix 1-8). Four-wing saltbush, winterfat and rabbitbrush were the only shrub species which contributed to total cover. The other shrub species were seedlings at the time of survival measurements and provided less than one percent cover.

For R_1 the ANOVA table (Table 1-2) for percent cover indicates that the statistical hypotheses H_{01}, H_{02}, H_{03}, H_{05}, H_{06}, H_{07}, H_{08}, and H_{09}, are rejected. The rejection of H_{02} and H_{03} indicates that at least one of the mulch treatment means and at least one of the fertilizer treatment means is different. The results of the multiple range tests of both mulch treatment means and fertilizer treatment means suggest that all four of the means are different in each case. The average percent cover of mulch treatments (Table 1-9) indicates that plantings with hydromulch resulted in the highest percent cover of planted species followed by plantings with no mulch at R_1. The average percent cover of fertilizer treatments (Table 1-9) indicates that plantings with no fertilizer resulted in the higher percent cover at R_1.

The differences in mulch effectiveness which occur for the parameters analyzed (planted species vs. total species) indicate that caution is necessary when interpreting the results of these studies, since differences which are inherent in the invader group may negate any statistical differences indicated by an analysis of variance. Invaders include two types of species. The first type includes barley and Russian thistle which invade as a result of their association

TABLE 1-9
SUMMARY OF PERCENT COVER
OF PLANTED, INVADER, AND TOTAL PLANT SPECIES
IN EACH OF SIXTEEN TREATMENTS ON RBOSP REVEGETATION SITE R_1
DURING AUGUST-SEPTEMBER, 1976.

Mulch	Fertilizer Application	Planted	Invader	Total
None	None	18	1	20
None	Fall	8	2	10
None	Spring	13	9	21
None	Fall-Spring	16	8	24
Hydromulch	None	20	4	23
Hydromulch	Fall	16	4	20
Hydromulch	Spring	17	3	20
Hydromulch	Fall-Spring	7	9	16
Straw	None	9	28	37
Straw	Fall	9	20	28
Straw	Spring	6	19	25
Straw	Fall-Spring	8	21	29
Netting & Straw	None	16	14	30
Netting & Straw	Fall	4	21	25
Netting & Straw	Spring	11	23	34
Netting & Straw	Fall-Spring	10	23	33

Average Percent Cover of Mulch Treatments

	Planted	Invader	Total
None	14	5	19
Hydromulch	15	5	20
Straw	8	22	30
Netting & Straw	10	20	31

Average Percent Cover of Fertilizer Treatments

	Planted	Invader	Total
None	16	12	28
Fall	9	12	21
Spring	12	14	25
Fall-Spring	10	15	25

(in large numbers) with the straw mulch. The other type invades in low numbers from undisturbed areas surrounding the revegetation plots. Therefore, a significant statistical difference in density is due to difference between the two invader types and is not due to the treatments which are presently being tested.

For R_2 the ANOVA table (Table 1-3) for percent cover indicates that the null hypotheses H_{02}, H_{05}, H_{06}, and H_{07} are rejected. The rejection of H_{02} indicates that at least one of the mulch treatment means is different. The multiple range test results suggest that each of the four means is significantly different at the 0.05 level. Comparison of the average percent cover of planted species for mulch treatments (Table 1-10) indicates that plantings with hydromulch result in the highest percent cover while plantings with hydromulch result in the next highest percent cover at R_2.

An ANOVA was performed to test each plant species and group of plant species at R_1 and R_2 with respect to percent cover. The results of these ANOVA are listed in Appendix 1-9.

1.3.4 Environmental Data

Soil samples collected at R_1 and R_2 for chemical analysis (Table 1-11 and 1-12) during November, 1975 indicate that the loamy soils are alkaline (pH of R_1 ranges from 7.8 to 8.8; pH of R_2 ranges from 7.7 to 9.5). In general, conductivity and organic matter levels are low. Nutrient levels are generally adequate except for phosphorus which is deficient. Nitrate levels are adequate at the surface but decrease greatly at subsurface levels.

Soil platings of samples collected during November, 1975 were made during 1976. The species which germinated in these platings are listed in Table 1-13.

Soil samples for soil moisture determinations were collected at R_1 and R_2 in June, September and November, 1976. The soil moisture levels occurring on R_1 (Table 1-14) were generally higher than those on R_2 (Table 1-15). This relationship is related to the site locations since R_1 is a northwest exposure

TABLE 1-10
SUMMARY OF PERCENT COVER
OF PLANTED, INVADER, AND TOTAL PLANT SPECIES
IN EACH OF SIXTEEN TREATMENTS ON RBOSP REVEGETATION SITE R_2
DURING AUGUST-SEPTEMBER, 1976.

Mulch	Fertilizer Application	Planted	Invader	Total
None	None	9	0	9
None	Fall	9	1	10
None	Spring	7	1	8
None	Fall-Spring	6	1	7
Hydromulch	None	9	1	10
Hydromulch	Fall	9	1	10
Hydromulch	Spring	15	2	17
Hydromulch	Fall-Spring	11	2	12
Straw	None	9	9	18
Straw	Fall	9	13	22
Straw	Spring	11	15	25
Straw	Fall-Spring	9	20	28
Netting & Straw	None	5	13	18
Netting & Straw	Fall	7	18	25
Netting & Straw	Spring	8	20	28
Netting & Straw	Fall-Spring	9	18	27
<u>Average Percent Cover of Mulch Treatments</u>				
None		8	1	6
Hydromulch		11	2	12
Straw		10	14	23
Netting & Straw		7	17	25
<u>Average Percent Cover of Fertilizer Treatments</u>				
None		8	6	14
Fall		9	8	17
Spring		10	10	20
Fall-Spring		9	10	19

TABLE 1-11

SELECTED CHARACTERISTICS OF THE SOILS PRESENT ON THE RBOSP REVEGETATION SITE R_1 IN NOVEMBER, 1975 PRIOR TO PLANTING

Sample No.	Depth (cm)	Texture[1]	pH	CEC (meq/100g)	Conductivity (μmhos/cm)	Na (Meq/100g)	Lime %	OM %	Org N lbs.	NO_3 ppm	P ppm	K ppm	Ca ppm	Mg ppm	Zn ppm	Fe ppm
1	0	Cl Lo	7.8	26	0.6	0.1	2.6	2.7	108	45.0	9.0	150	3900	140	0.3	2.0
1	15	Si Lo	8.1	24	0.5	0.1	9.0	4.4	120	6.0	8.0	58	3600	110	0.1	1.6
1	30	Si Lo	8.1	24	0.5	0.1	9.0	3.3	120	5.0	2.0	53	3600	130	0.2	1.8
2	0	Sn Lo	7.9	21	0.8	0.1	1.7	2.1	94	32.0	11.0	120	3200	110	0.2	1.7
2	15	Sn Lo	8.1	22	0.5	0.1	2.5	1.9	85	7.0	2.0	63	3200	140	0.1	1.0
2	30	Si Lo	8.2	20	0.3	0.1	8.9	3.1	120	4.0	2.0	52	2900	140	0.1	1.2
2	45	Si Lo	8.2	18	0.3	0.1	8.8	2.6	104	3.0	2.0	40	2500	140	0.2	1.4
3	0	Cl Lo	7.8	24	0.4	0.1	1.1	1.9	76	41.0	10.0	100	3500	240	0.2	1.5
3	15	Si Lo	8.2	24	0.3	0.1	7.8	2.0	80	4.0	4.0	46	3500	210	0.1	1.0
3	30	Si Lo	8.5	21	0.3	0.1	8.9	2.5	100	3.0	1.0	33	2900	250	0.1	1.0
3	45	Si Lo	8.8	21	0.3	0.2	8.9	2.1	84	2.0	1.0	28	2700	340	0.1	1.4

[1] Si = Silt
Sn = Sand
Lo = Loam
Cl = Clay

TABLE 1-12

SELECTED CHARACTERISTICS OF THE SOILS PRESENT ON THE RBOSP REVEGETATION SITE R_2 IN NOVEMBER, 1975 PRIOR TO PLANTING

Sample No.	Depth (cm)	Texture[1]	pH	CEC (meq/100g)	Conductivity (μmhos/cm)	Na (Meq/100g)	Lime %	OM %	Org N lbs.	NO_3 ppm	P ppm	K ppm	Ca ppm	Mg ppm	Zn ppm	Fe ppm
1	0	Sn Lo	8.1	17	0.8	0.1	8.3	3.3	100	64.0	15.0	64	2700	63	0.2	1.8
1	15	Sn Lo	8.2	16	0.5	0.1	8.8	1.4	63	4.0	2.0	29	2500	32	0.1	1.7
1	30	Sn Lo	8.6	15	0.3	0.1	6.8	0.6	27	2.0	1.0	20	2300	40	0.1	1.2
1	45	Lo	9.5	20	1.0	1.1	9.0	1.1	50	5.0	1.0	34	2000	350	0.1	1.2
2	0	Sn Cl Lo	7.9	23	0.8	0.1	2.8	3.3	120	84.0	10.0	88	3500	130	0.2	3.4
2	15	Si Lo	8.2	25	0.8	0.3	8.8	4.4	120	22.0	7.0	51	3600	150	0.2	4.4
2	30	Sn Lo	8.8	20	3.0	1.0	9.0	2.4	100	9.0	3.0	23	2700	160	0.2	1.6
3	0	Sn Cl Lo	7.7	22	1.0	0.1	4.8	4.5	120	91.0	14.0	150	3400	110	0.3	5.6
3	15	Cl Lo	7.9	25	0.6	0.1	9.0	5.2	120	20.0	7.0	62	3600	250	0.3	4.8
3	30	Sn Lo	8.2	20	0.8	0.1	9.0	2.5	100	4.0	8.0	34	2700	320	0.2	1.9

[1] Si = Silt
Sn = Sand
Lo = Loam
Cl = Clay

TABLE 1-13

PLANT SPECIES WHICH GERMINATED FROM THE SOIL PLATINGS COLLECTED AT R_1 AND R_2 IN NOVEMBER, 1975

Sample Number	Location	
	R_1	R_2
1	None	*Senecio multilobatus* *Gutierrezia sarothrae*
2	*Gutierrezia sarothrae*	*Arabis* sp. *Gutierrezia sarothrae*
3	*Haplopappus* sp. Unknown forb[1]	None

[1]Forb could not be identified

TABLE 1-14

SOIL MOISTURE IN PERCENT WATER[1] FOR LOCATION R_1 DURING JUNE, SEPTEMBER, AND NOVEMBER 1976.

Sample No.	Soil Depth											
	0 cm			15 cm			30 cm			45 cm		
	June	Sept	Nov	June	Sept	Nov	June	Sept	Nov	June	Sept	Nov
1	2.2	4.8	4.2	17.2	13.4	12.5	16.3	15.5	12.5	15.0	13.5	11.7
2	4.6	5.8	4.2	15.6	13.1	9.4	15.0	12.9	10.5	12.1	12.4	10.4
3	2.8	4.1	4.3	16.1	13.1	13.3	14.8	14.5	13.3	12.3	12.8	14.6
Composite (S_1, S_2 & S_3)	3.2	4.9	4.3	16.3	13.2	11.7	15.4	14.3	12.1	13.1	12.9	12.2

TABLE 1-15

SOIL MOISTURE IN PERCENT WATER[1] FOR LOCATION R_2 DURING JUNE, SEPTEMBER, AND NOVEMBER 1976.

Sample No.	Soil Depth											
	0 cm			15 cm			30 cm			45 cm		
	June	Sept	Nov	June	Sept	Nov	June	Sept	Nov	June	Sept	Nov
1	1.5	3.9	6.4	18.8	13.4	14.8	13.7	12.2	14.8	12.0	11.1	13.1
2	1.9	4.0	3.0	14.7	12.4	11.7	12.6	11.4	12.2	10.8	12.2	12.4
3	1.5	5.0	6.2	16.1	11.8	10.1	11.9	14.6	11.5	11.9	13.0	10.1
Composite (S_1, S_2 & S_3)	1.7	4.3	5.2	16.5	12.5	12.2	12.7	12.7	12.6	11.5	12.1	11.9

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[1] Black (1965). $\dfrac{(\text{Weight of wet soil + tare}) - (\text{Weight of dry soil + tare})}{(\text{Weight of dry soil + tare}) - (\text{tare})}$

and R_2 is a southeast exposure. Both sites had low soil moisture at the surface regardless of the sampling date. Values at the 15 cm, 30 cm, and 45 cm depths generally decreased from June through November indicating that the soil moisture of subsurface soils was depleted during the growing season and was recharged by winter snow.

The rainfall measured at R_1 and R_2 during mid-June to November, 1976 is presented in Table 1-16. These rainfall amounts were similar to the precipitation measurements obtained at meterological site 1 during the same period (Progress Report 8, 1976).

1.4 Summary

Emergence density, survival density, and percent cover data were collected during the first growing season for the revegetation experiments initiated in 1975. Results of an analysis of variance on these data indicate that significant differences occur among species and among treatments. The results of the statistical analyses are complex and one must be cautious when interpreting and drawing conclusions concerning these data.

The analyses of variance show significant differences for a number of variables. While the density data indicate differences among mulch and fertilizer treatments, these differences cannot be considered conclusive unless appropriate statistical analyses are conducted.

Generally, the first year data indicate significant differences among mulch treatments. Future measurements of percent cover and biomass should provide more valid tests of the effects of fertilizer. Therefore, the first year of data represents inconclusive evidence regarding a choice of future revegetation treatments. After the present three year revegetation experimental program is completed, more conclusive recommendations can be made for future revegetation efforts on Tract C-a.

TABLE 1-16

RAINFALL RECORDED AT THE RBOSP REVEGETATION SITES (R_1 & R_2) FROM JUNE THROUGH MID-NOVEMBER 1976.

	R_1			R_2		
DATE	STATION 1[1] (in)	STATION 2[2] (in)	AVERAGE (in)	STATION 1[1] (in)	STATION 2[2] (in)	AVERAGE (in)
6/12	0.08	0.07	0.08	0.08	0.07	0.08
6/24	1.31	1.35	1.33	1.33	1.39	1.36
7/24	0.41	0.45	0.43	0.43	0.49	0.46
8/4	0.60	0.60	0.60	0.65	0.64	0.65
8/31	0.69	0.70	0.70	0.74	0.79	0.77
11/21	0.92	0.89	0.91	0.93	0.84	0.89
TOTALS	4.01	4.06	4.04	4.16	4.22	4.19

[1]Station 1 is located at the upper end of the revegetation plot

[2]Station 2 is located at the lower end of the revegetation plot

2.0 - REVEGETATION EXPERIMENTS INITIATED IN 1976

2.1 Objectives

The objectives of the 1976 RBOSP revegetation experimental program are:

- to determine if the simulated artificial soil profile can inhibit upward capillary migration of salts from Tosco II processed shale
- to determine which plant species (when sown in a composite mixture on the simulated artificial soil profile) are best adapted to the environmental conditions existing on a south exposure on Tract C-a
- to determine if several mulches applied to the simulated artificial soil profile are effective in aiding establishment and survival of plant species and in reducing erosion
- to compare growth and survival of native shrubs that are sown directly or planted as tubelings on the simulated artificial soil profile.

2.2 Methods

2.2.1 Location and Schedule

The 1976 revegetation site (R_3) is located southeast of drill pad #AM 6369, east of the road connecting Wolf Ridge Road and drill pad #GS 6292 (Figure 2-1) in the southeast corner of the tract (Section 10). The test site is located on the southeast exposure and has a natural slope of approximately 20%.

Table 2-1 outlines the schedule of field events for the 1976 revegetation experimental program on Tract C-a.

2.2.2 Seedbed Preparation

The 1976 revegetation experiments are designed to simulate the artificial soil profile for the overburden/processed shale disposal piles as described in

LEGEND

TRACT OUTLINE

DRILL HOLES

STREAM GAGING STATIONS

AIR QUALITY TOWERS

ROADS

GULF - STANDARD (INDIANA)

RIO BLANCO OIL SHALE PROJECT

TRACT C-a

RIO BLANCO COUNTY, COLORADO

0 3000

Figure 2-1. Location of Revegetation Test Plots R_1, R_2, and R_3

TABLE 2-1

SCHEDULE OF FIELD EVENTS FOR THE REVEGETATION STUDIES INITIATED IN 1976 ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO 1976 - 1978

1976	J	F	M	A	M	J	J	A	S	O	N	D
Site Selection								Δ				
Field Work												
Seedbed Preparation										Δ		
Planting											Δ	
Measurements of Plant Response to Treatments												
Soil Analysis												
Sample Collection for Chemical Analyses										Δ		
Moisture Determination										Δ		
Salinity Determinations												Δ

1977	J	F	M	A	M	J	J	A	S	O	N	D
Site Selection												
Field Work												
Seedbed Preparation												
Planting												
Measurements of Plant Response to Treatments						Δ		Δ				
Soil Analysis												
Sample Collection for Chemical Analyses												
Moisture Determination						Δ		Δ		Δ		
Salinity Determinations											Δ	

1978	J	F	M	A	M	J	J	A	S	O	N	D
Site Selection												
Field Work												
Seedbed Preparation												
Planting												
Measurements of Plant Response to Treatments								Δ				
Soil Analysis												
Sample Collection for Chemical Analyses												
Moisture Determination						Δ		Δ		Δ		
Salinity Determinations											Δ	

the RBOSP Detailed Development Plan (1976). The following strata simulate the proposed artificial soil profile.

0.15m (0.5 ft) topsoil
0.30m (1 ft) subsoil
0.90m (3 ft) segregated mine run (12 x 0 in. size)
0.52m (1.75 ft) compacted Tosco II processed shale

The soil profile was prepared by separately stockpiling topsoil (6 in.), subsoil (12 in.), and excavated sandstone (12 in.). Mine run material was then obtained by excavating 3 ft of rock material from the revegetation site and stockpiling it. A plastic sheet was laid into a 5.5 ft deep prepared area to insure that no contamination of ground water will occur and to facilitate collection of any leachate for analysis. Due to the limited availability of Tosco II processed shale, approximately 20 in. of processed shale was placed on top of the plastic sheet. The processed shale was compacted to prevent penetration or leaching and to simulate the 5 ft surface layer of the compacted processed shale of the proposed disposal pile configuration. Measurements of the processed shale density and depth at the 1976 experimental plot are presented in Progress Report 9. The control plot was underlain by approximately 20 in. of sandstone excavated from the revegetation site and which had been previously stockpiled. Following compaction of the processed shale, 3 ft of segregated mine run overburden (12 x 0 in. size) was bulldozed over the processed shale and the excavated sandstone of the control plot. Estimates of the percent fines occurring in the artificial soil profile are presented in Progress Report 9. This 3 ft layer of mine run overburden represents a combination of the large and crushed rock layers as outlined in the RBOSP Detailed Development Plan. The topsoil and subsoil were replaced in proper sequence. The edges of the simulated artificial soil profile were graded to improve the aesthetic appearance of the revegetation plots.

Catchment basins were constructed along the upper edge of the artificial soil profile to reduce erosion.

2.2.3 Plot Layout

The 1976 revegetation site utilizes a 53 x 53 m (174 x 174 ft) area (0.3 ha or 0.70 ac) (Figure 2-2). An approximate 23 m (75 ft) wide boundary area surrounding the revegetation site was disturbed by operation of machinary, removal and stockpiling of vegetation, and temporary stockpiling of soil material. Thus a total of 1.0 ha (2.41 ac) was disturbed by the 1976 experiments.

At the site, each 6 x 6 m plot received one treatment and the 6 treatments were replicated six times for a total of 36 plots (Figure 2-2). Each plot is surrounded by a 1 m buffer zone, except that a 5-6 m buffer zone exists along the outermost perimeter of the treatment plots to reduce microclimatic effects and a 3 m buffer occurs in the center of the plot at the interface of the processed shale and control area. These microclimatic effects are expected to more severely affect the perimeter of the simulated profile and thus a larger perimeter buffer zone has been provided at the perimeter than between plots. Treatments were allocated randomly in each of three complete blocks located adjacent to each of the plots. Within each 6 x 6 m treatment plot, a minimum of three 1.0 x 0.5 m subplots will be randomly established and permanently marked for subsequent data collection.

The test site was fenced with four-strand barbed wire to discourage large grazers, primarily feral horses and cattle.

2.2.4 Sowing Methods

Grass, forb, and shrub seed was seeded as a composite mixture after the simulated artificial soil profile had been prepared and the seedbed graded. Seed was drilled into the ground using a conventional grassland drill equipped with depth bands and a single-seed box and agitator. Rice hulls were added to the seed mixture as a "filler substance" to increase the bulk of seed in the seed box. Depth bands insured that seed was not drilled deeper than 2 cm (0.5 to 0.75 in.). It is expected that drilling will be necessary for the large scale

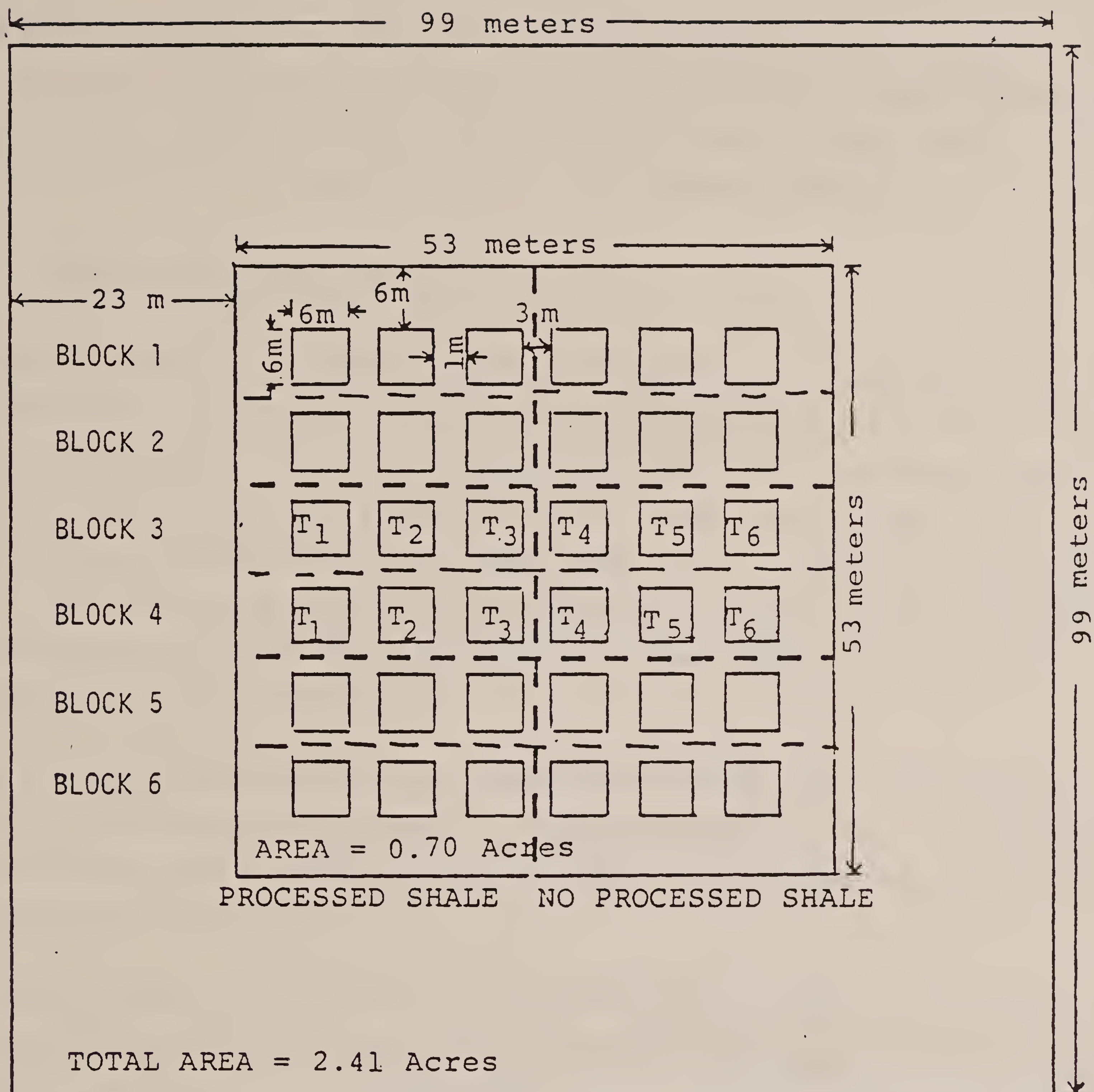

FIGURE 2-2. GENERALIZED PLOT LAYOUT FOR REVEGETATION PLOTS ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO (INITIATED IN 1976). Six treatments (T_1 - T_6) are replicated six times and randomly selected.

operation of seeding the disposal piles and it is desired that the present studies simulate the large scale operation as much as possible.

Seed was drilled in 60 m long strips along the contours of the slope. Since the drill has a 2.5 m (8 ft) drilling span, two passes were made to seed the 6 x 6 m plots, leaving a narrow unseeded band along the edge of each plot. Drilling resulted in a spacing of 5 to 7 in. between planting rows.

2.2.5 Species and Sowing Rates

A composite mixture of grasses, forbs, and woody plants (Table 2-2) was sown in preference to pure species stands. This mixture consists of both introduced and native species. Nearly all the species (Table 2-2) have demonstrated success in earlier species adaptability trials when sown in pure stands in the sagebrush and pinyon-juniper ecosystems (Cook et. al., 1974; Sims and Redente, 1974). With several exceptions, the preliminary results of the 1975 RBOSP revegetation plots indicate that these species are successful when sown in a composite mixture on Tract C-a.

While it would be advisable to use local seed sources (NAS, 1974), they are generally not available at present. For the present studies, it was necessary to obtain seed from a number of private companies and governmental agencies throughout the arid west.

For the 1976 test, approximately 20 lb of seed per ac were sown, with non-grasses (forbs and woody plants) in slight excess (11.0 lb) of the 9.5 lb of grasses. The total pure live seed (PLS) per acre is 14.7 lb (grass = 7.92; forb = 2.97; woody plants = 3.81).

Direct seeding of a composite seeding mixture will be compared to plantings of tubelings, a popular type of containerized seedling. Tubelings will be grown from the same seed lots that were used for direct seeding by the USDA Shrub Science Laboratory. Five shrub species (excluding *Amelanchier alnifolia*) and pinyon pine will be utilized for the tubeling treatment. Tubelings will be a 18 cu in. size (2 in. x 1.5 in. x 6 in.). The containers are made of high

TABLE 2-2

PLANT SPECIES SUITABILITY AND PROJECTED SOWING RATES (lb/acre) OF VIABLE SEED FOR SPECIES UTILIZED IN THE REVEGETATION EXPERIMENTS INITIATED IN 1976 ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO 1976 - 1978

wrong!

not P.L.S.

Species	Suitability Rating[a]	Seeding Rates (lbs/acre)
GRASSES		
Luna pubescent wheatgrass (Agropyron trichophorum var. Luna)	2,4,6,8,9	2.0
Rosana western wheatgrass (Agropyron smithii var. Rosana)	4,5,8,9	2.0
Sodar streambank wheatgrass (Agropyron riparium var. Sodar)	3,5,8,9	1.5
Indian ricegrass (Oryzopsis hymenoides)	2,4,5,7,9	1.0
Manchar brome (Bromus inermis)	1,6,8	1.5
Green needlegrass (Stipa viridula)	2,5,7	1.5
Subtotal		9.5
FORBS		
Lewis flax (Linum lewisii)	2,5	1.00
Lutana cicer milkvetch (Astragalus cicer var. Lutana)	6,11	0.75
Utah sweetvetch (Hedysarum utahensis)	2,5	0.50
Madrid yellow sweetclover (Melilotus officinalis var. Madrid)	2,4,5,9,11	0.75
Rocky Mountain penstemon (Penstemon strictus var. bandera)	3,5,9	0.50
Common daisy (Chrysanthemum leucanthemum)	3,5,9	0.50
Subtotal		4.00
SHRUBS		
Bitterbrush (Purshia tridentata)	1,5,9,10,11	1.5
Mountain mahogany (Cercocarpus montanus)	1,5,10	1.5

TABLE 2-2(Continued)

Species	Suitability Rating[a]	Seeding Rates (lbs/acre)
SHRUBS (Continued)		
Fourwing saltbush (Atriplex canescens)	1 (seeds), 3,4,5,9	1.25
Winterfat (Eurotia lanata)	1,5,10	.75
Rubber rabbitbrush (Chrysothamnus nauseosus)	3,5,9,10,11	.75
Serviceberry (Amelanchier alnifolia)	2,5,10,11	.75
Subtotal		6.5
TREES		
Pinyon pine (Pinus edulis)	3,5,9,11	.4
Subtotal		.4
TOTAL		20.4

[a]Suitability ratings are:

1	highly palatable	7	bunch grass
2	moderately palatable	8	sod grass
3	unpalatable	9	drought resistant
4	soil stabilizer	10	browse
5	native to Colorado[b]	11	cover for game
6	introduced species		

[b]Underlining indicates species observed on site as part of the environmental baseline studies.

impact styrene with vertical corrugations to enhance downward growth of the roots and to discourage root spiraling. There is a hole at the bottom of each tube to encourage lateral root development.

The tubelings will be planted in each treatment plot by hand in early or mid-June at a rate of 18 tubelings per plot (1800 tubelings per ac) using three tubelings of each of the six species. Tubelings will be randomly planted and the location and species of each tubeling will be mapped for later reference.

2.2.6 Treatments

For the 1976 tests, a total of six treatments were applied using all possible combinations of the following variables:

Simulated Artificial Soil Profile

1. Simulated artificial soil profile underlain by excavated sandstone ("control").
2. Simulated artificial soil profile underlain by Tosco II processed shale.

Mulch Type and Application

1. No mulch
2. Hydromulch with wood fiber (0.75 tons per ac)
3. Native hay followed by crimping (2 tons per ac)

These mulch treatments are similar to the 1975 mulch treatments with several exceptions. The straw mulch treatment has been replaced with a native hay mulch which will eliminate the problem of introducing grain species such as barley and should reduce the problem of weedy species, such as Russian thistle, if good quality native hay is obtained. The straw mulch with plastic netting has not been included in the 1976 treatments. Although qualitative observations of the 1975 revegetation plots indicate that no wind or water erosion has occurred in plots where the straw and netting treatment has been properly applied, the treatment's erosion-reducing potential can only be properly tested on a more extreme slope.

Because conclusive results of the fertilizer treatments of the 1975 revegetation experiments are not expected until biomass is estimated in 1978, the fertilizer treatment will be constant in the experiments initiated in 1976. A fertilizer application will be made at the beginning of the growing season in 1977, when soils data from Tract C-a will be available, to determine the rate and type of fertilizer to be applied.

2.2.7 Plant Response Parameters

The following plant response parameters will be measured for each treatment: (1) number of emerged seedlings per plot, (2) number of surviving seedlings per plot, and (3) percent cover.

Table 2-3 gives the season of measurement for each parameter and the taxa involved. A qualitative measure of alien species success will be obtained from in-situ counts of germination in buffer areas and from germination in soil samples collected from buffer areas and placed in the greenhouse. In addition, baseline data will be available on plant community composition and structure of the plot areas prior to site preparation (Limnetics, Inc., 1975).

2.2.8 Environmental Data

Soils data will be collected periodically (Table 2-3) during the study period to determine more closely the causal links between plant response and the soil factors. Soils data will include:

1. Baseline soil chemistry
2. Soil moisture
3. Soil salinity

Three baseline soil chemistry samples were collected prior to planting at the test site. Texture, pH, cation exchange capacity, conductivity, percent organic matter, and available nitrogen, phosphorus and potassium were determined by standard laboratory techniques.

TABLE 2-3

PLANT RESPONSE PARAMETERS MEASURED IN THE REVEGETATION STUDIES INITIATED IN 1976
ON OIL SHALE TRACT C-a, RIO BLANCO COUNTY, COLORADO

Parameter	Time of Measurement	Taxa Involved
Number of emerged seedlings per plot	first spring following fall planting, i.e., beginning of first growing season	each planted species
Number of surviving seedlings	end of first growing season	each planted species
Percent cover	end of each growing season	each species

Soil moisture in soil samples collected at 15 cm intervals throughout the soil column will be measured using standard gravimetric techniques. Soil moisture determinations will be made periodically (Table 2-3) on three samples at the test site during the growing season.

Soil salinity determinations were made at the time of planting and will be made at the end of each growing season. Soil samples (total of 108 samples per year) will be collected at each treatment plot by soil tube from depths of 0, 1-25, and 26-50 cm. Three samples from each row will be composited for analyses (total of 36 samples will be analyzed per year). Sample analyses will include electrical conductivity to determine the presence of salt and to detect any upward migration of salts. Cations (Na^{+}, Mg^{++}, and Ca^{++}) are the ions expected to initially rise by capillary action into the soil profile (Barth, 1976; Olsen, 1976). Conductivity estimates will therefore define the effectiveness of the simulated artificial soil profile in reducing upward migration from the processed shale.

During construction of the artificial soil profile, perforated plastic pipe was inlaid for collection of leachate. Leachate will be collected at three locations: (1) at the top of the compacted shale, (2) beneath the compacted shale, and (3) at the bottom of the sandstone filler on the control side of the experimental area. The leachate will be analyzed for toxic materials which may be leached from the shale pile. Duplicate samples will be taken at each sampling station twice each year (once after spring snow melt and once following heavy precipitation during the growing season). The samples will be analyzed for conductivity, fluoride, lead, zinc, mercury, boron, arsenic, barium, copper, and chromium.

Rainfall measurements will be made from April through October at monthly intervals, using standard rain gauges similar to those currently being utilized in the 1975 revegetation plots. Rainfall measurements will provide estimates of the actual precipitation received at the revegetation plots.

2.3 Results

The 1976 RBOSP revegetation site (R_3) was prepared during the period of September 29 - November 8, 1976. Prior to disturbing the site in preparation for seeding, the vegetation at location R_3 was characterized (Table 2-4). Site R_3 occurs in sagebrush vegetation dominated by Artemisia tridentata. The site is adjacent to pinyon-juniper habitat and individuals of pinyon-pine (Pinus edulis) and juniper (Juniperus osteosperma) are scattered throughout. Bitterbrush (Purshia tridentata) is common.

Soil samples were collected prior to disturbance for chemical analysis and soil moisture determinations. Soil samples for conductivity measurements were collected after the seedbed preparation was completed but these analyses are not yet complete.

Soil chemistry analyses (Table 2-5) indicate that the loamy soils are alkaline (range of 7.5 to 9.2). Conductivity ranges from 2.0 to 3.5 a range which may affect very salt-sensitive plants. Percent organic matter is low which is common in arid soils and nutrient levels are average with the exception of phosphorus which is deficient. These chemical analyses indicate that the fertilizer to be applied in spring 1977 will be a nitrogen-phosphorus mixture; no potassium will be necessary. Following review of the RBOSP soils report for Tract C-a and vicinity, a fertilizer mixture will be chosen.

Determinations of soil moisture samples collected in September 1976 (Table 2-6) indicate that soil moisture generally decreased as depth of sample increased. The soil moisture levels were similar to those collected from R_1 and R_2 (Tables 1-18 and 1-19) during September, 1976 except that samples taken from 0 cm generally had a higher moisture content than the R_1 and R_2 samples.

TABLE 2-4

RELATIVE ABUNDANCE OF THE VEGETATION PRESENT ON THE RBOSP REVEGETATION SITE R_3 ON SEPTEMBER 27, 1976 PRIOR TO PLANTING

Plant Species	Relative Abundance*
Artemisia tridentata	5
Purshia tridentata	4
Pinus edulis	3
Chrysothamnus nauseosus	3
Chrysothamnus viscidiflorus	3
Oryzopsis hymenoides	3
Chrysothamnus depressus	2
Haplopappus sp.	2
Juniperus osteosperma	2
Senecio multilobatus	1
Opuntia polyacantha	1
Sphaeralcea coccinea	1
Phlox hoodii	1
Hedysarum sp.	1
Aster sp.	1
Penstemon osterhoutii	1
Physaria floribunda	1
Antennaria sp.	1
Amelanchier utahensis	1
Bryophyte	1

Total Cover = 45%

*Relative Abundance:
1 = very rare
2 = rare
3 = occasional to common
4 = abundant
5 = very abundant

TABLE 2-5

SELECTED CHARACTERISTICS OF THE SOILS PRESENT ON THE RBOSP REVEGETATION SITE R_3 IN SEPTEMBER, 1976. PRIOR TO PLANTING

Sample No.	Depth (cm)	Texture[1]	pH	CEC (meq/100g)	Conductivity (μmhos/cm)	Na (Meq/100g)	Lime %	OM %	Org N lbs.	NO_3 ppm	P ppm	K ppm	Ca ppm	Mg ppm	Zn ppm	Fe ppm
1	0	Sn	7.9	11	3.5	0.5	4.9	1.6	72	37	16	85	3400	100	0.6	1.9
1	15	Sn Lo	8.3	12	3.0	0.7	8.1	2.6	100	40	12	50	3400	280	0.5	1.1
1	30	Si Lo	8.5	18	2.0	0.7	8.4	2.8	112	14	10	35	2900	330	0.4	1.0
1	45	Sn Lo	8.8	12	3.0	1.6	6.6	1.9	86	11	7	29	3100	400	0.3	0.8
2	0	Sn Lo	8.2	10	2.6	0.6	3.3	1.5	68	19	7	70	3200	85	0.4	1.3
2	15	Si Lo	8.8	14	2.3	1.7	9.1	1.7	68	8	3	35	2900	300	0.3	1.4
2	30	Lo	8.9	16	2.8	2.1	9.1	2.7	100	10	31	40	2800	380	0.4	1.5
3	0	Lo	8.3	16	2.5	0.6	6.5	2.3	100	20	8	70	3500	100	0.1	1.4
3	15	Lo	8.8	14	2.6	1.1	7.0	2.4	100	9	7	38	3400	360	0.2	0.7
3	30	Si Lo	9.2	13	2.5	7.0	6.5	1.5	60	8	8	50	3100	540	0.3	0.9

[1] Si = Silt
Sn = Sand
Lo = Loam
Cl = Clay

TABLE 2-6

SOIL MOISTURE IN PERCENT WATER[1] FOR LOCATION R_3
DURING SEPTEMBER, 1976

Sample No.	Soil Depth			
	0 cm	15 cm	30 cm	45 cm
1	13.9	12.7	10.8	9.2
2	11.4	11.5	10.6	Bedrock
3	9.8	7.3	8.7	Bedrock
Composite (S_1, S_2, S_3)	11.7	10.4	10.0	9.2

[1] Black (1965). $\frac{\text{(Weight of wet soil + tare) - (Weight of dry soil + tare)}}{\text{(Weight of dry soil + tare) - (tare)}}$

Native Plants Greenhouse Study
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Table 1. Analyses of the three soils received from Rio Blanco Oil Shale Company.

	Top Soil	Overburden	Processed Shale
Texture	Loam	Loam	Loam
pH	7.9	8.0	10.8
ECe	0.8	1.2	5.3
P (ppm)*	6.0	1.5	18.0
K (ppm)*	95.0	65.0	142.0
N (ppm)	50.5	18.3	1.0
CA (meq/l)	2.5	0.8	6.2
NA (meq/l)	1.2	8.9	27.4
Mg (meq/l)	0.7	0.7	0.03
Lime	++	++	+
Arsenic (ppm)**	0.650	0.385	1.570
Boron (ppm)**	1.950	3.500	18.740
Fluoride (ppm)**	12.461	8.531	56.449
Molybdenum (ppm)**	2.050	3.050	20.520
Selenium (ppm)**	0.050	0.210	0.440

* extracted using $NaHCO_3$

** measured with atomic absorption spectophotometer

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Rio Blanco Oil Shale Company
2851 South Parker Road Suite 500
Aurora, Colorado 80014 (303) 695-2400
A GENERAL PARTNERSHIP
GULF OIL CORPORATION • STANDARD OIL COMPANY (INDIANA)

April 14, 1982

Mr. Peter A. Rutledge
Deptuty Conservation Manager
Area Oil Shale Office
131 North 6th - Suite 300
Grand Junction, Colorado 81501

Dear Pete:

Over the last year there has been some discussion between RBOSC and the Oil Shale Office staff regarding the leachate collection system on Experimental Revegetation Plot R-3. To date, no leachate has been collected from the three portions of the system. In order to obtain a better understanding of the movement of moisture through the reconstructed soil profile on Plot R-3, RBOSC plans to assess moisture status using a neutron probe depth moisture gauge. Access tubes will be installed this year and, although initial measurements will be obtained this year, we expect more accurate data to be available beginning in 1983.

The 1982 field season represents the sixth year of growth for planted species on Plot R-3. We feel that sufficient time has elapsed for roots, particularly those of shrub species, to enter the 3 ft. capillary barrier portion of the reconstructed profile. In order to discern whether or not roots are intermingling with the underlying TOSCO II processed shale, RBOSC also plans an assessment of root penetration via direct observation within a trench which intersects all portions of the reconstructed profile as well as the processed shale. It may be possible to situate this trench such that it intersects a portion of the leachate collection system. If so, this would allow us to confirm whether or not the system is functional.

I understand that David Boyce and Dave Oberwager have discussed these proposed studies to some extent and we welcome any further suggestions which you or your staff may have.

Sincerely,

GCSlawson Jr

G. C. Slawson, Jr.
Manager, Environmental Affairs

DAB/GCS/ntm

xc: Bob Elderkin
Dave Oberwager
David Boyce

bxc: W. Jack Clark
P. V. O'Connor